Improvements to Tropical Cyclone Model Forecasts

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LONG-TERM GOALS

The long-term goal is to investigate, develop, and implement the ability to analyze and predict the tropical cyclone (TC) structure and intensity, and to reduce the occurrence of large-error track forecast through the use of high-resolution numerical prediction systems and satellite observations.

OBJECTIVES

The objective is to improve TC initialization by the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS^{TM}) through the use of synthetic observations and to improve COAMPS^{TM} TC structure and intensity forecasts through improvement of model numerics and physics.

APPROACH

Our approach is to develop a tropical cyclone initialization system for high-resolution COAMPS^{TM} that uses the Navy Atmospheric Variational Data Assimilation System (NAVDAS) to analyze high-resolution synthetic observations for tropical cyclone initialization. The synthetic observations are constructed by fitting observed TC structure parameters to a modified Rankine vortex model. The observed TC structure parameters are obtained from warning messages issued by the Joint Typhoon Warning Center (JTWC) and from 34 kt and 50 kt wind radii retrieved from available satellite observations such as QuikSCAT. We will evaluate and upgrade COAMPS^{TM} model physics to improve TC structure and intensity forecast. We will evaluate numerical techniques such as two-way movable inner mesh, interactive nesting and dynamical initialization to look for further improvement to the TC structure and intensity forecast. We develop tools to objectively measure model performance in the TC structure and intensity forecast. We leverage other programs at NRL that address satellite data processing, model numerics and physics, data assimilation, air-ocean and air-wave coupling, and validation to integrate the necessary technology into a complete high-resolution tropical cyclone prediction system.

WORK COMPLETED

1. We have enhanced the movable inner mesh capability of COAMPS^{TM} for operational tropical cyclone forecast to most efficiently use high resolution for TC structure and intensity forecast. Following the method used in the GFDL tropical cyclone model, we have developed and implemented codes in COAMPS^{TM} to dynamically track a selected TC during model forecast. There are several ways to define the center of a tropical cyclone, e.g., at minimum sea level pressure or maximum

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14. ABSTRACT
The long-term goal is to investigate, develop, and implement the ability to analyze and predict the tropical cyclone (TC) structure and intensity, and to reduce the occurrence of large-error track forecast through the use of high-resolution numerical prediction systems and satellite observations.

15. SUBJECT TERMS

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relative vorticity. However, due to large amplitude gravity waves near TC centers these minimum or maximum centers may oscillate in time. To define a smoothed TC movement and better represent the center of an area covered by TC circulation, we use the "mass center" to track a selected TC. The mass center (x_m, y_m) is defined as the gravity center of pressure deficits with respect to a reference pressure, $x_m = \frac{\sum \delta P_i x_i}{\sum \delta P_i}, y_m = \frac{\sum \delta P_i y_i}{\sum \delta P_i}$,where δP is the pressure deficit. The reference pressure is computed as the average of minimum and maximum sea level pressure within 300km by 300km Square around the previous cyclone center. When a high-resolution inner mesh is selected to move follow a tropical cyclone, the center of the inner mesh is initially set at the TC position. The TC position is tracked in every time step in the forecast. When the TC moves away from the inner mesh center more then one grid distance of its mother mesh, the inner mesh is moved to a new location where the TC center is at the mesh center again. For incremental update runs, the initial inner mesh center is initially positioned at the predicted TC location from the first guess. The inner mesh center is then moved to match the TC center within a 6-hour period. The dynamical tracking algorithm is implemented in the Massive Parallel Processing version of COAMPS™.

2. We have developed a method to retrieve 35kt and 50kt wind radii from available QuikSCAT surface wind observations to improve accuracy in describing initial TC structure. The method checks if there are sufficient QuikSCAT observations within a 600km radius of any tropical cyclone. If there are enough data, the surface wind speed observations are azimuthally averaged in 4 quadrants at different distances, in 10km increments, from a TC center up to 600 km (Fig. 1). The averaged wind speed at different distances is least square fitted to a fifth order polynomial. The radii of 34kt and 50kt wind are then computed from the polynomial. The final observed 34kt and 50kt wind radii are determined as the average from available JTWC warning messages and the QuikSCAT retrieval.

3. We have been working on developing an objective method to identify tropical cyclone circulation centers from model forecast date during the model run. The circulation centers are then used to compute maximum wind speed and 34kt and 50kt wind radii of identified tropical cyclones in every hour of the forecast period. We are evaluating the stability and accuracy of this objective method to output maximum wind speed and 34kt and 50kt wind radii of tropical cyclones from the COAMPS™ forecast.

RESULTS

More than 100 COAMPS™ forecast have been run to test the enhancement of a movable inner mesh for TC forecast application. Comparison of forecasts from moving grids and fixed grids indicates that the grid movement introduces very minimal errors (Fig. 2). The movable inner mesh logic ensures terrain height at all co-located grid points of different nest levels to be the same so that the inner grids can be smoothly moved over complex terrain areas (Fig. 3). However, when a mesh moves out from its initial location, the pressure difference between the sea level and ground surface is not known at newly moved-in areas. Therefore, the standard COAMPS sea level reduction method that requires the pressure difference cannot be used in moved grids. We use a different sea level reduction method following the Eta-model for movable grid nests. The reduction method produces noisier sea level pressure over land at lateral boundary zones. However, the sea level pressure over land is not involved in incremental update cycles so that the noise will not affect the model forecast of the next run.

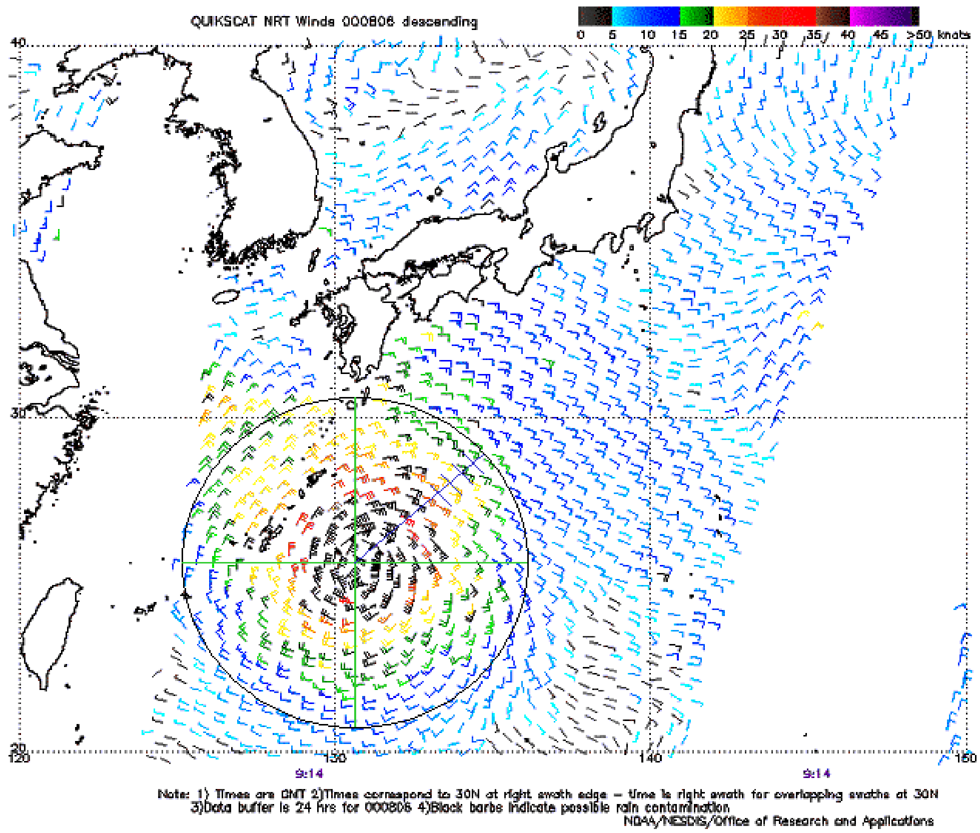

Figure 1. Retrieval of 34kt and 50kt wind radii from QuikSCAT observations in 4 quadrants.

A method of retrieving TC 34kt and 50kt wind radii from QuikSCAT observations has been evaluated for two year-2002 tropical cyclones, Phanfone and Rusa. There are 7 different sets of wind direction and speed data available in the FNMOC QuikSCAT data files. After detailed evaluation, we decide to use only the two sets of the wind retrieved by FNMOC and NESDIS. The FNMOC retrieval has more missing data due to its conservative consideration in rain contamination. We use averaged values of the two retrievals to determine the radii of 34kt and 50kt wind through a least square fitting. Tables 1 and 2 show the comparison of 34kt and 50kt wind radii for Phanfone and Rusa from JTWC warning messages and QuikSCAT observations. The average of the values from JTWC and QuikSCAT retrieval should provide more accurate measurements of TC 34kt and 50kt wind radii. More evaluation is underway to determine the merit of the QuikSCAT retrieval.

IMPACT/APPLICATIONS

The movable inner mesh enhancement in COAMPS^{TM} for tropical cyclone forecast allows users to apply very high resolution to resolve complicated multi-scale interactions near a TC center for structure and intensity forecast but with much less computational requirement. The high resolution improves COAMPS TC structure forecast. The retrieval of TC 34kt and 50kt wind radii from QuikSCAT surface wind provides direct observational measurement of the two important parameters to improve accuracy in describing TC initial structure.

TRANSITIONS

The tropical cyclone initialization system developed for COAMPS™ has been delivered to FNMOC and been operational since 1 August 2002. The upgrade of movable inner mesh for TC forecast has been installed in the master trunk of COAMPS™ under the configuration management at NRL, and is getting ready for operational installation at FNMOC.

RELATED PROJECTS

Related 6.2 projects within PE 0602435N are *High Resolution Mesoscale Model Prediction and Validation* funded by ONR, and the NRL base program BE-35-2-32 *Satellite/NWP Data Fusion for Weather Assessment;* and a related 6.4 project as part of this RTP is under PE 0603207N *Tropical Cyclone Forecast Systems*.

PUBLICATIONS

Liou, C. -S., 2002: High resolution numerical modeling on tropical cyclone structure and track. Proceedings of INDO-US Workshop on Weather and Climate Modelling. March 2002, New Delhi, India, in press.

Liou, C. -S., 2002: Prediction of tropical cyclone wind structure in Navy operational mesoscale model. Preprints, 25th Conference on Hurricanes and Tropical Meteorology, May 2002, San Diego, 333-334.

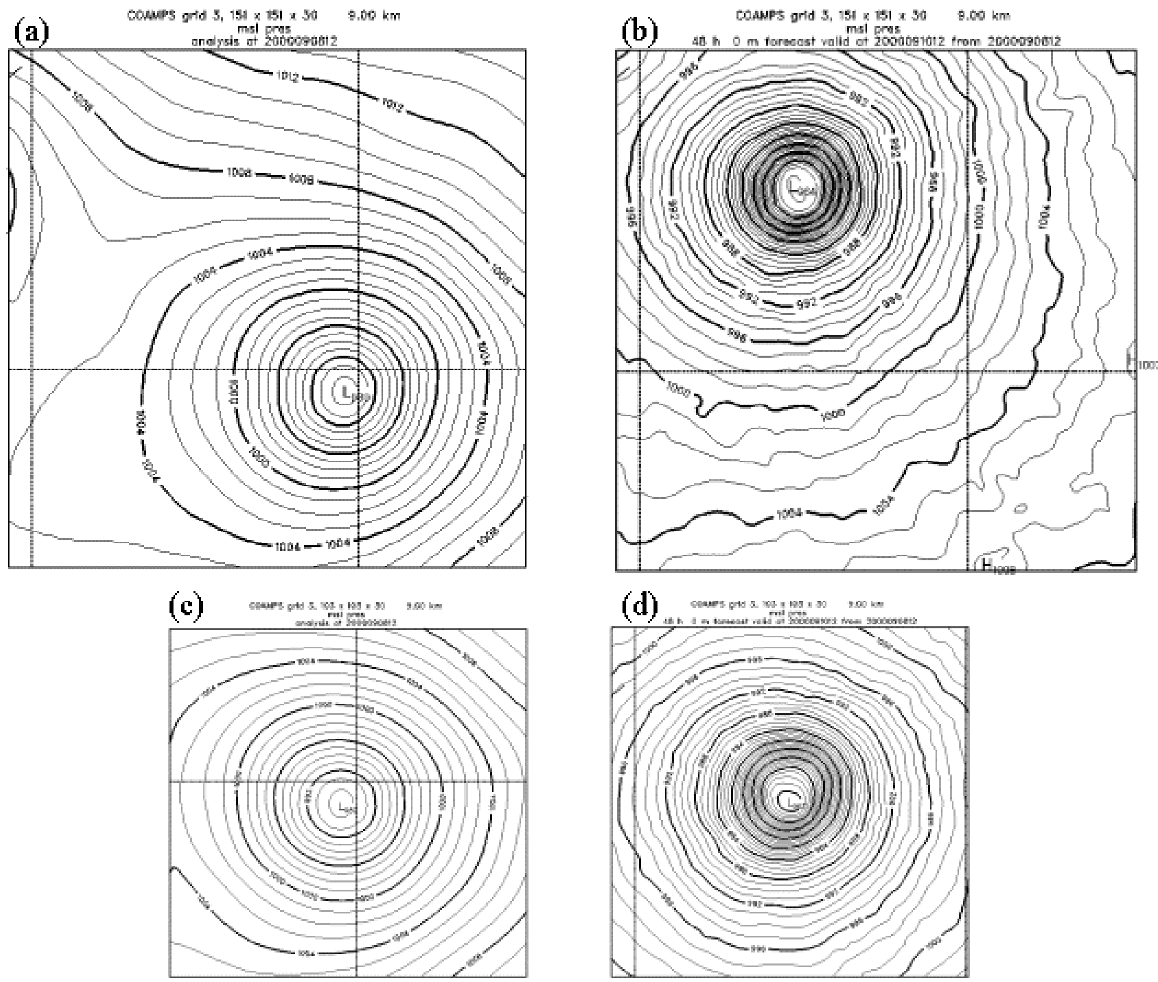

Figure 2. Comparison of sea level pressure from (a) analysis, (b) 48h forecast of larger-area fixed grids, and (c) analysis, (d) 48h forecast of moving grids. The maximum difference between the 48h sea level pressure forecasts in (b) and (d) is about 1 mb.

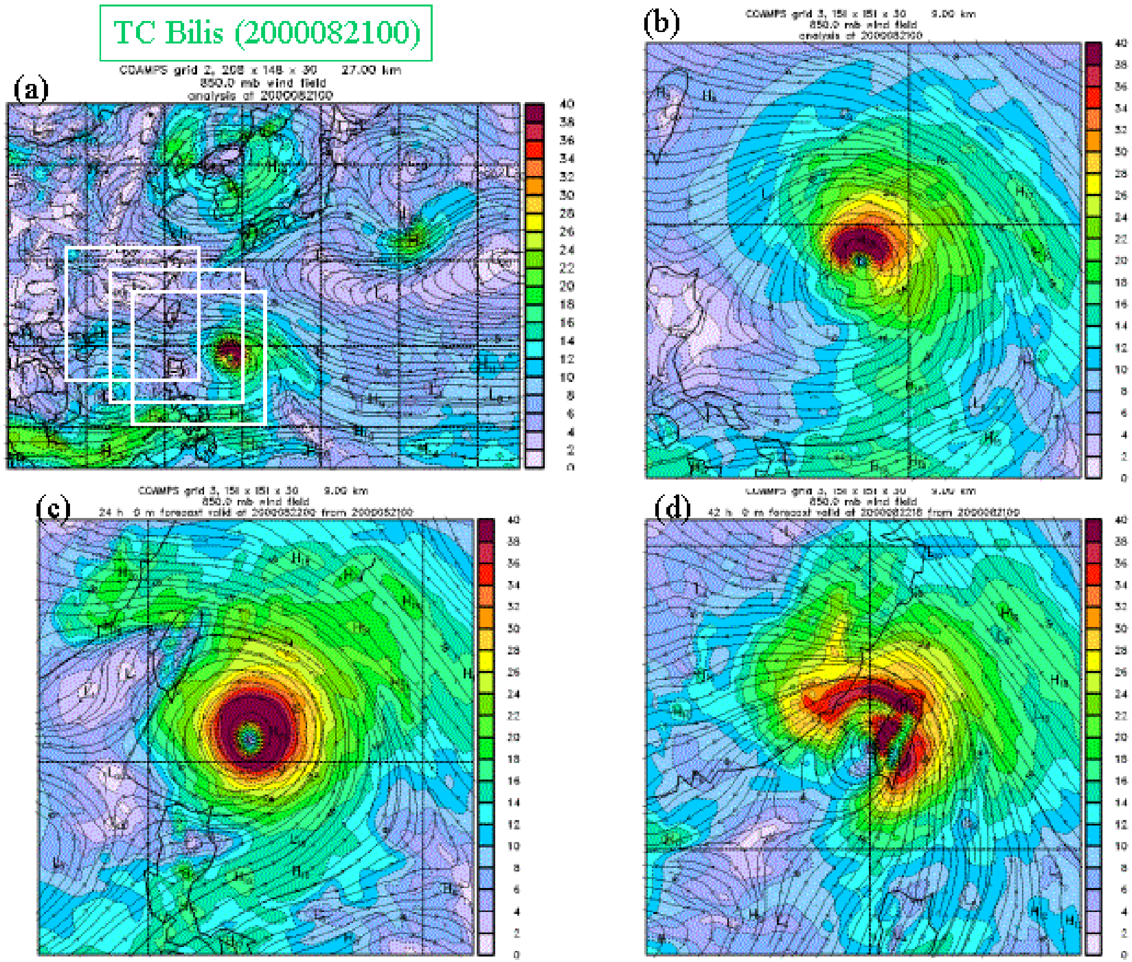

Figure 3. Example of moving grid application for TC Bilis forecast, (a) locations of 9km inner meshes at different forecast periods, (b) 850mb wind analysis of the 9km mesh at initial time, (c) 850mb wind forecast of the 9km mesh at 24h forecast, and (d) 850mb wind forecast of the 9km mesh at 42h forecast when Bilis moved over Taiwan.

R50:	**JTWC**	**QuikSCAT**	**Average**
Q1:	45	59	52
Q2:	45	41	43
Q3:	45	---	45
Q4:	45	139	92

R34:	**JTWC**	**QuikSCAT**	**Average**
Q1:	200	226	213
Q2:	200	77	139
Q3:	150	84	117
Q4:	100	202	151

Table 1. 50kt and 34kt wind Radii (nm) at 4 quadrants from JTWC warning message and QuikSCAT Retrieval for Phanfone at 2002081318.

R50:	JTWC	QuikSCAT	Average	R34:	JTWC	QuikSCAT	Average
Q1:	70	48	59	Q1:	140	155	148
Q2:	60	---	60	Q2:	120	124	122
Q3:	60	18	39	Q3:	100	136	118
Q4:	70	16	43	Q4:	140	163	152

Table 2. 50kt and 34kt wind Radii (nm) at 4 quadrants from JTWC warning message and QuikSCAT Retrieval for Rusa at 2002082518.